Magnetosphere-Ionosphere Coupling as Revealed in Ground and Space-Based Observations of Total Electron Content

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Radiation Belt Storm Probes Science Working Group Meeting
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Outline

- **Magnetosphere-Ionosphere Coupling, Geomagnetic Storms, and the Radiation Belts**
- **Ground-based Total Electron Content**
- **Space-based Total Electron Content**
- **Summary**

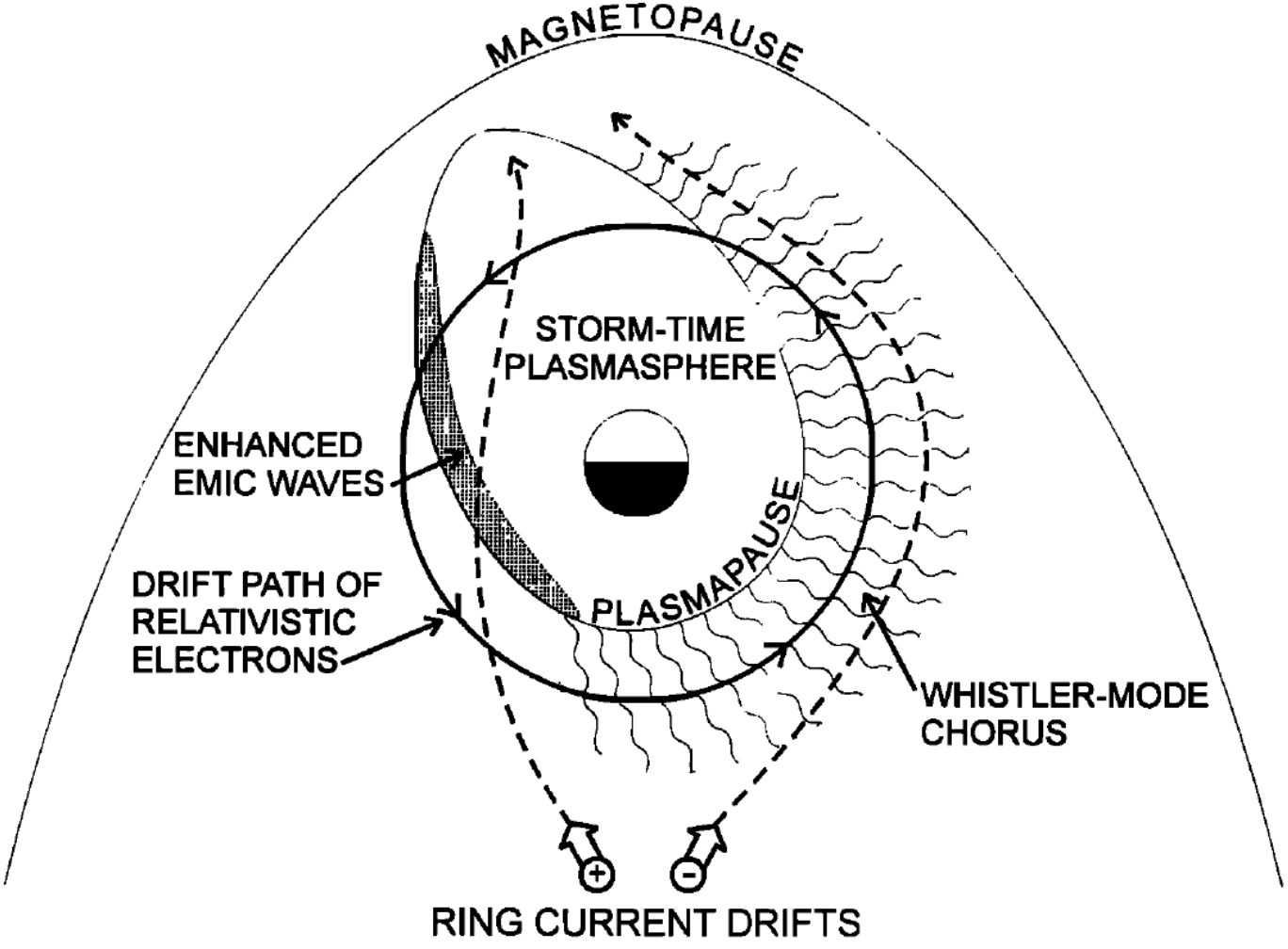
"…a key defining aspect of the LWS program is the development and implementation of "systems science" capability in order to gain a global understanding."
Living With A Star Science Architecture Team Report, 2001

"…Encourage and undertake a systems perspective of geospace."
CEDAR The New Dimension Strategic Vision Document, 2011

MI Coupling, Geomagnetic Storms, and Radiation Belts

- **Magnetosphere-ionosphere coupling plays a major role in the evolution of geomagnetic storms**
- **Radiation belt response to geomagnetic storms is a "delicate balance" (Reeves et al., *GRL* 2003)**
- **Solar wind drivers of thermosphere-ionosphere storms is a major topic of study within T-I community**
- **Ground-based TEC measurements depend sensitively on the plasmasphere boundary and magnetospheric convection (electric fields)**
- **Space-based TEC measurements provide information on ionospheric conductivities caused by particle precipitation, which in turn affect magnetosphere currents and structure**

Plasmasphere/Plasmapause



Summers, Thorne and Xiao, 1998

Total Electron Content Measurements Using GPS

Global Positioning System Satellite Transmitter (20,230 km altitude)

RF Delay ~ $1/f^2$
L1 = 1575 GHz
L2 = 1227 GHz
16.2 cm delay at L1
= 1 TEC Unit
= 10^{16} el/m^2

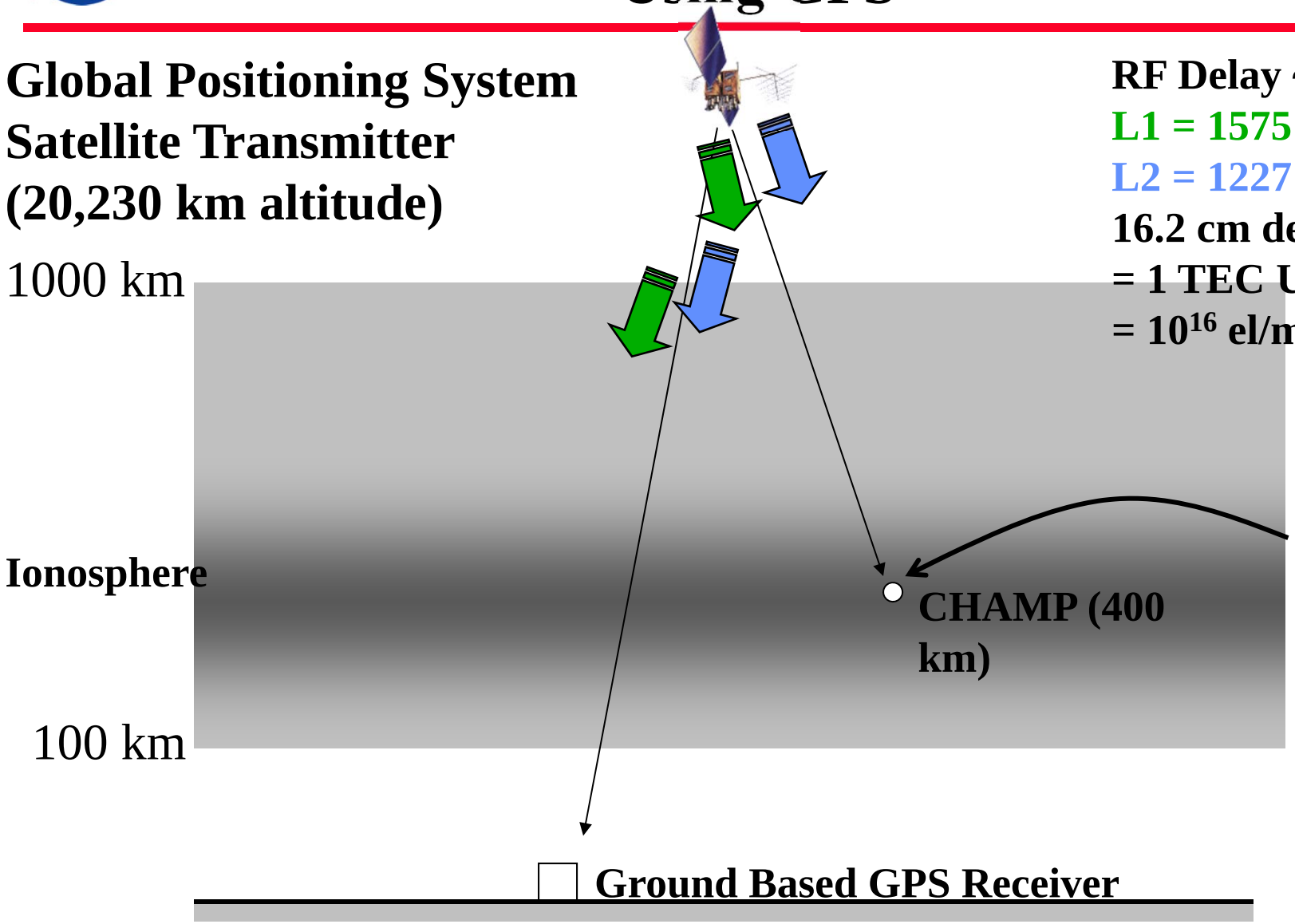
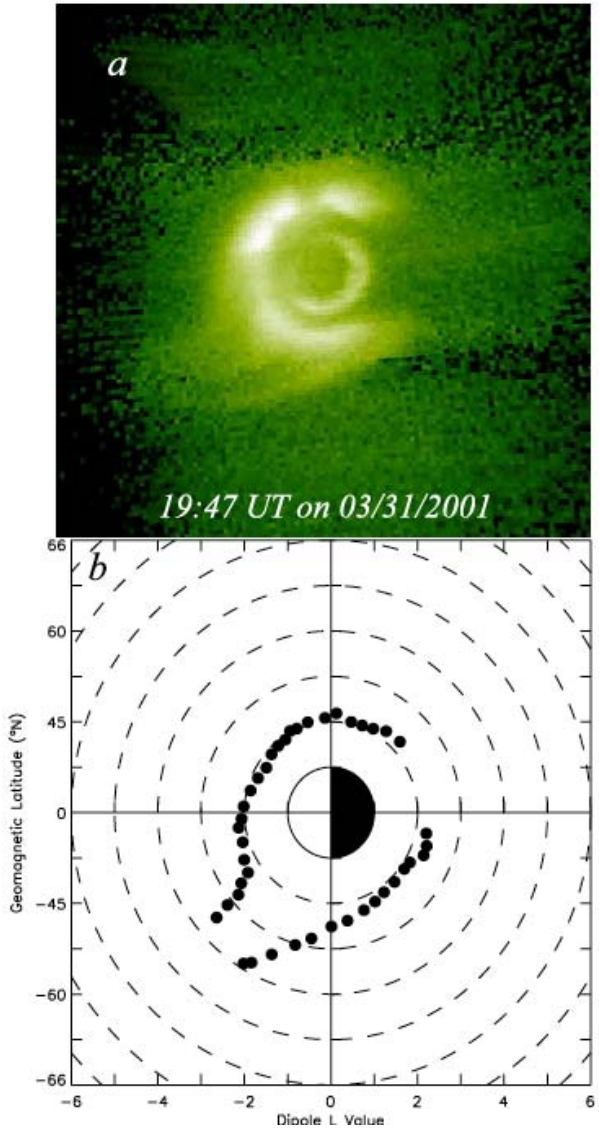
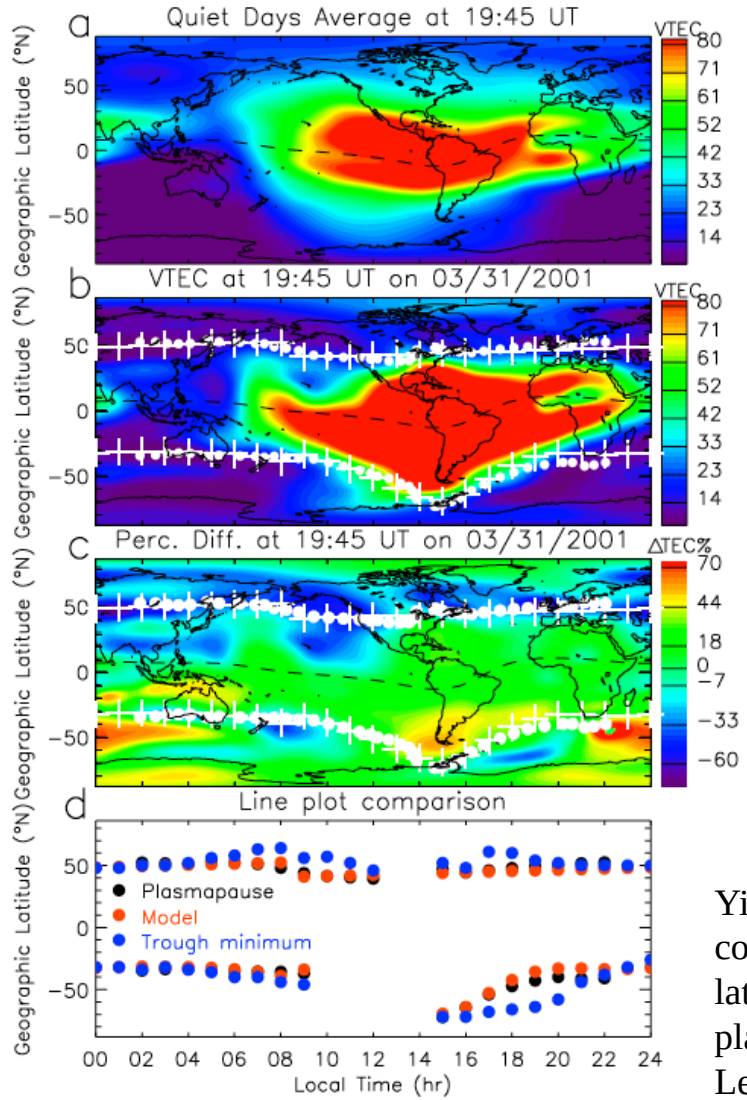


IMAGE and TEC: Plasmapause and TEC trough

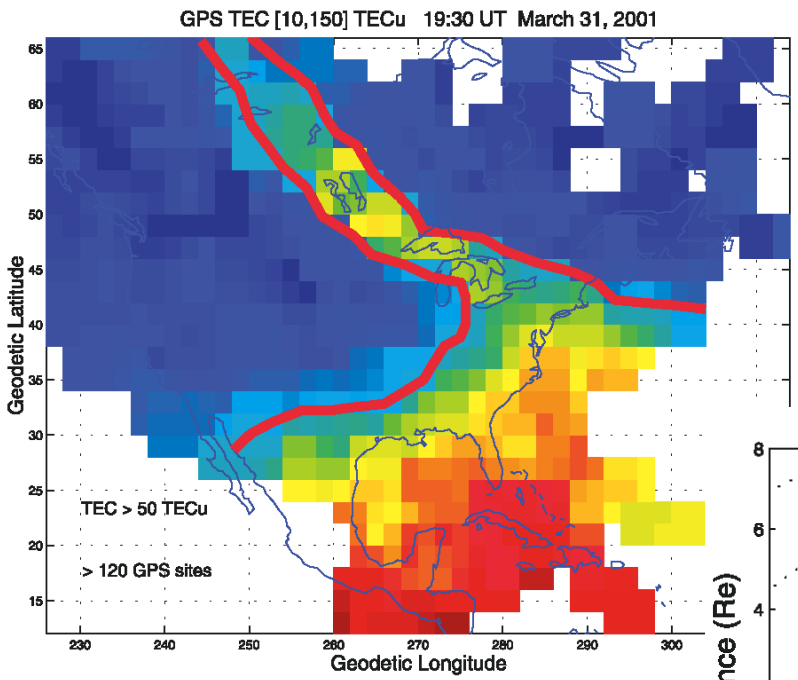




Global Ionospheric Maps (GIM), generated using ground based GPS receivers, are used to detect the globally extended mid-latitude trough; while global IMAGE EUV pictures are used to estimate the plasmapause position…The two independent observations (mid-latitude trough and plasmapause positions) and an empirical model have been compared on a global scale and found to be in excellent agreement.

Yizengaw, E., et al., " The correlation between mid-latitude trough and the plasmapause, Geophys. Res. Lett., 2005.

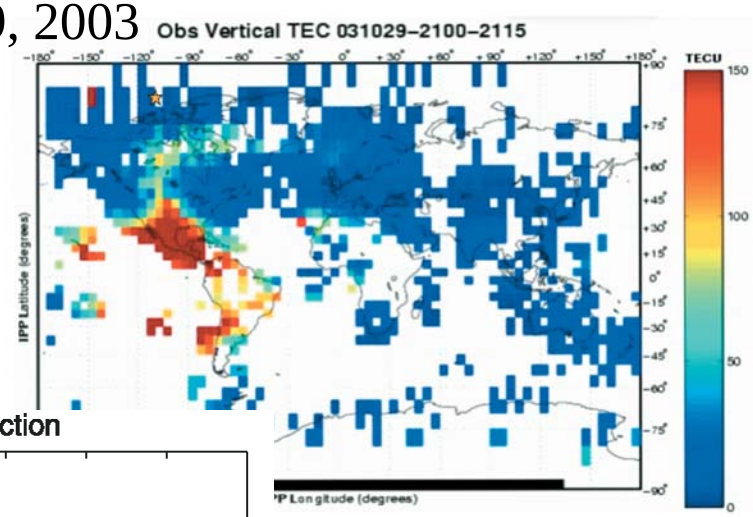
Signature of TEC Plumes in TEC

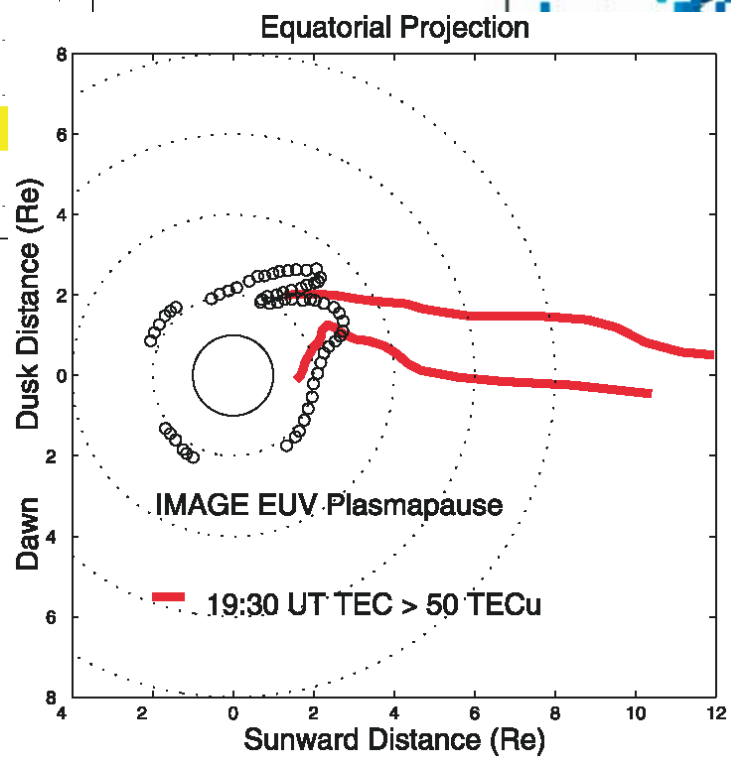


Foster et al., "Ionospheric signatures of plasmaspheric tails", Geophys. Res. Lett., 2002

March 31, 2001

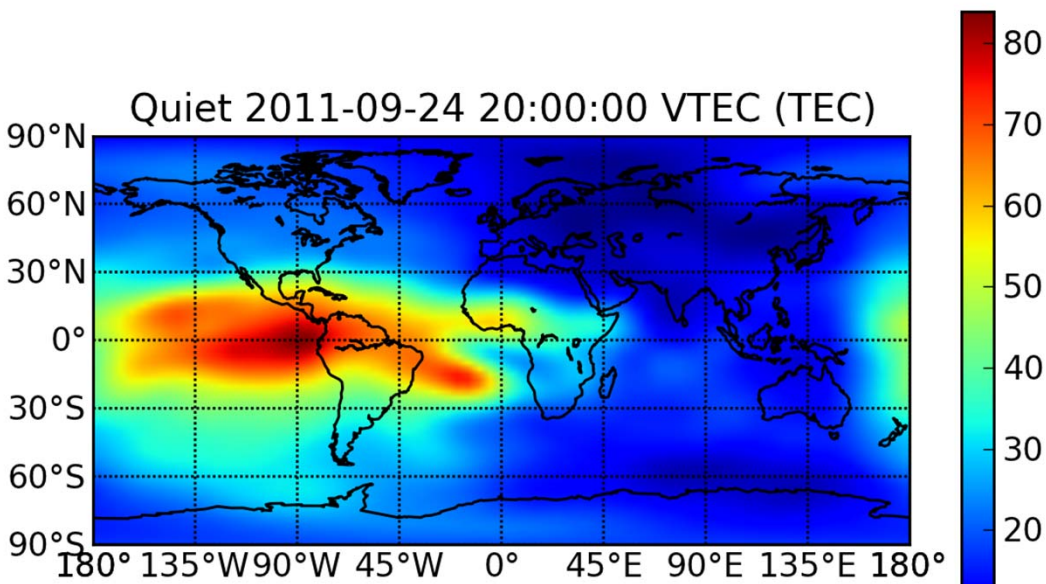
October 29, 2003

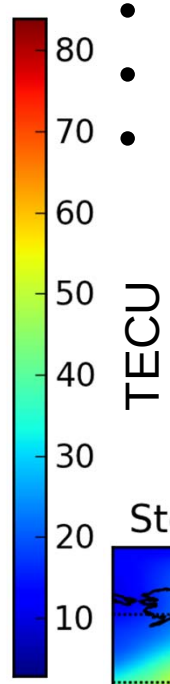




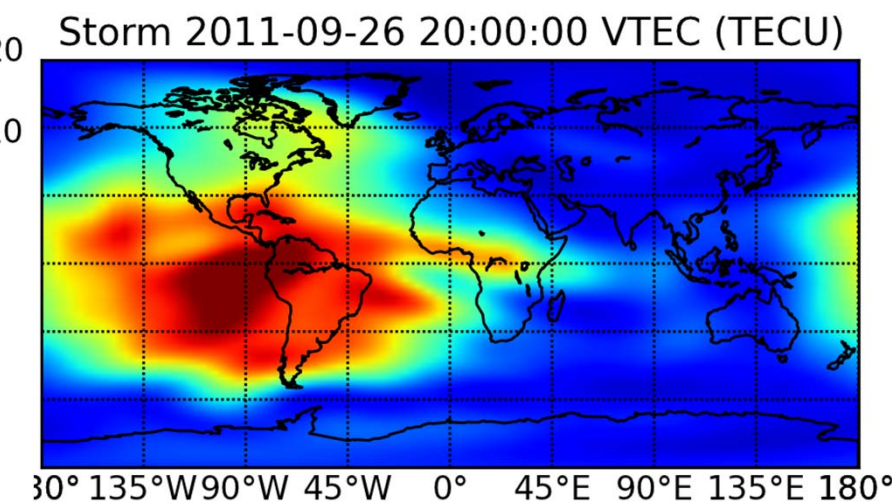
Mannucci et al., "Hemispheric Daytime Ionospheric Response To Intense Solar Wind Forcing", AGU Monograph V159, 2005

Global TEC Maps Database





- Trough/plasmapause observations
- Plume structure
- Large scale convection

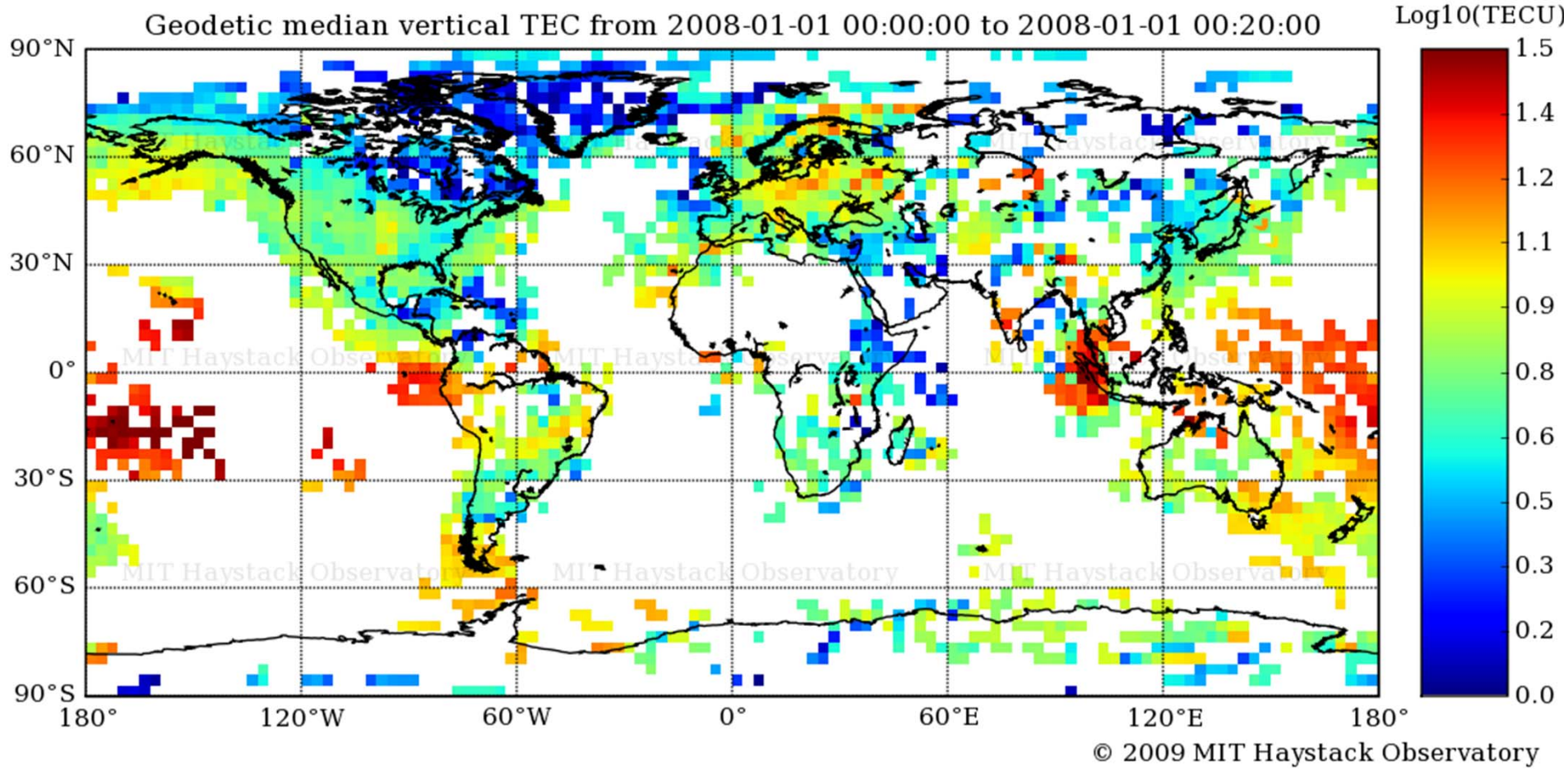


International GNSS Service ("Global Navigation Satellite Systems")

TEC maps available 1998-2012

http://cddis.nasa.gov/gnss_datasum.html
ftp://cddis.gsfc.nasa.gov/pub/gps/products/ionex/

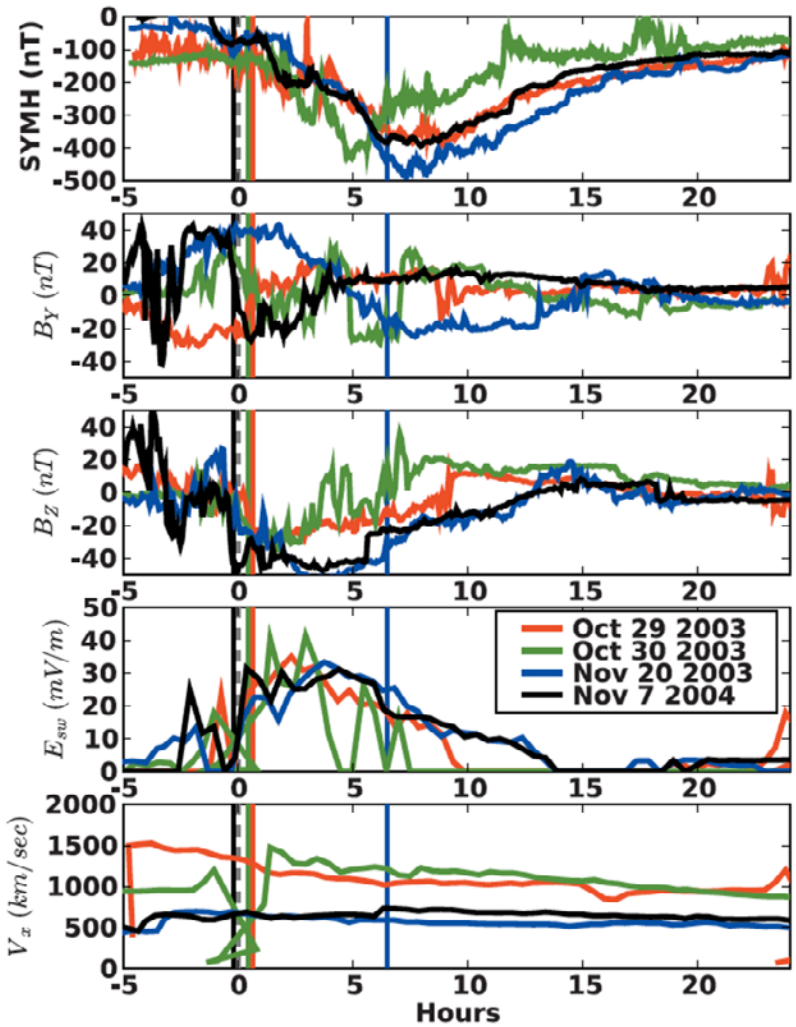
Madrigal Product



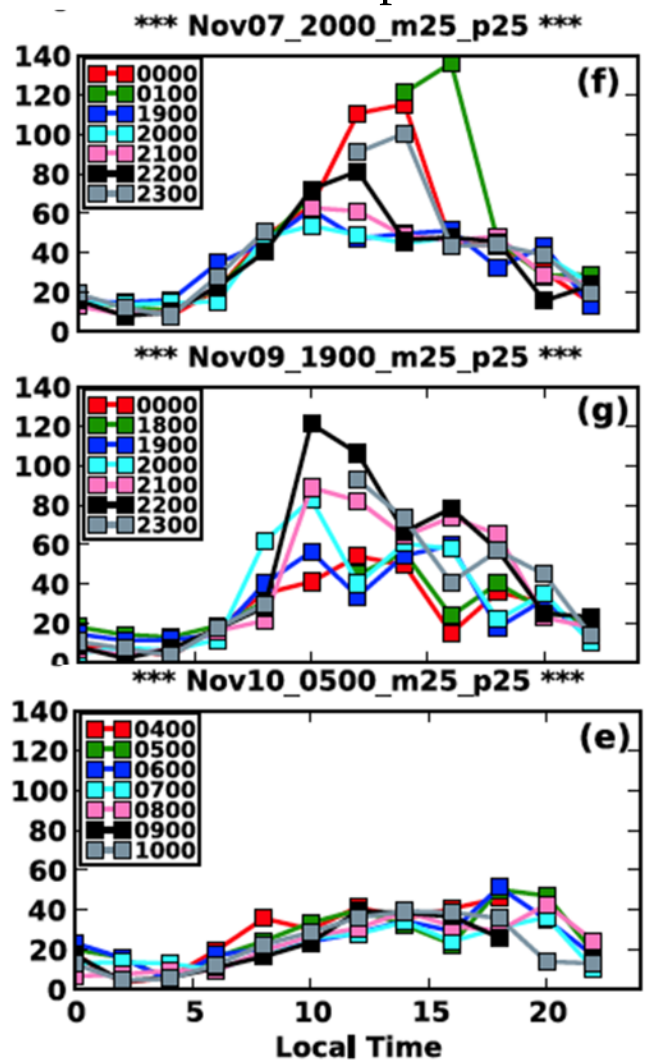
Maps available 1998-2012
http://cedar.openmadrigal.org/

"If You've Seen One Storm" – Variability of Prompt Stormtime TEC Response

Lack of prompt TEC increase in Nov 2003 Superstorm

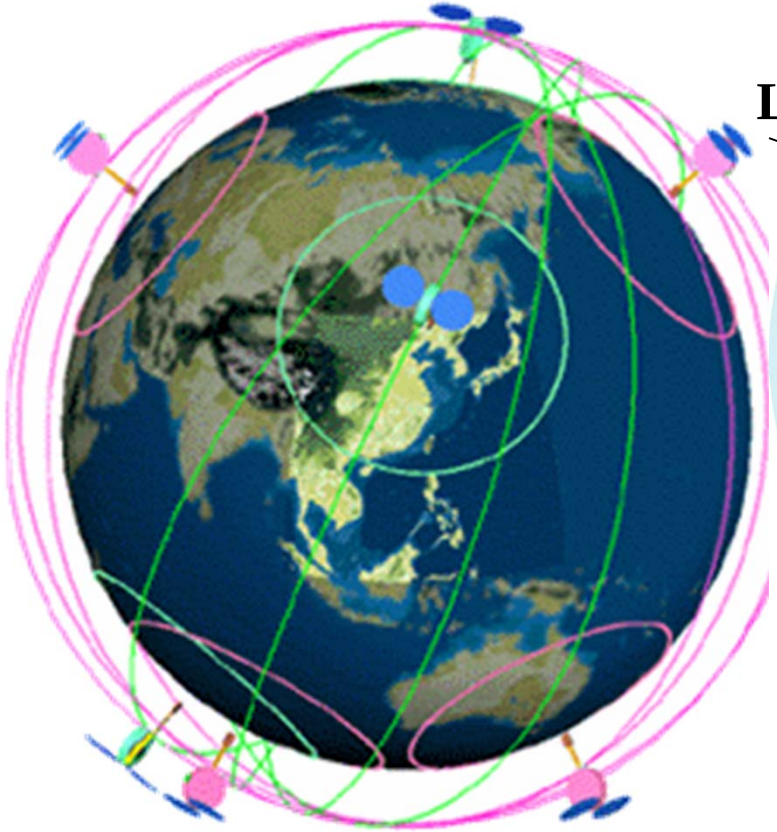


Absence of TEC increase in Nov 10, 2004 superstorm

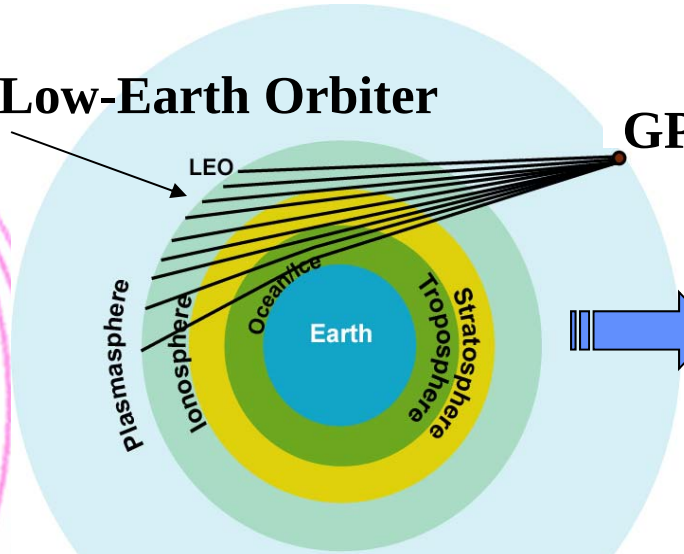


- **Follow on paper in preparation**
- **Tentative conclusion: solar wind variables that affect global magnetospheric structure may be affecting prompt penetration electric fields in Nov 2003 storm**

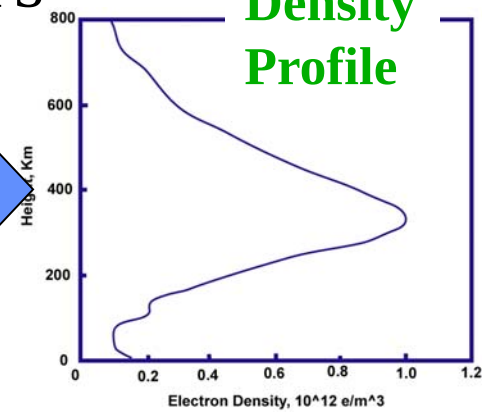
COSMIC Constellation



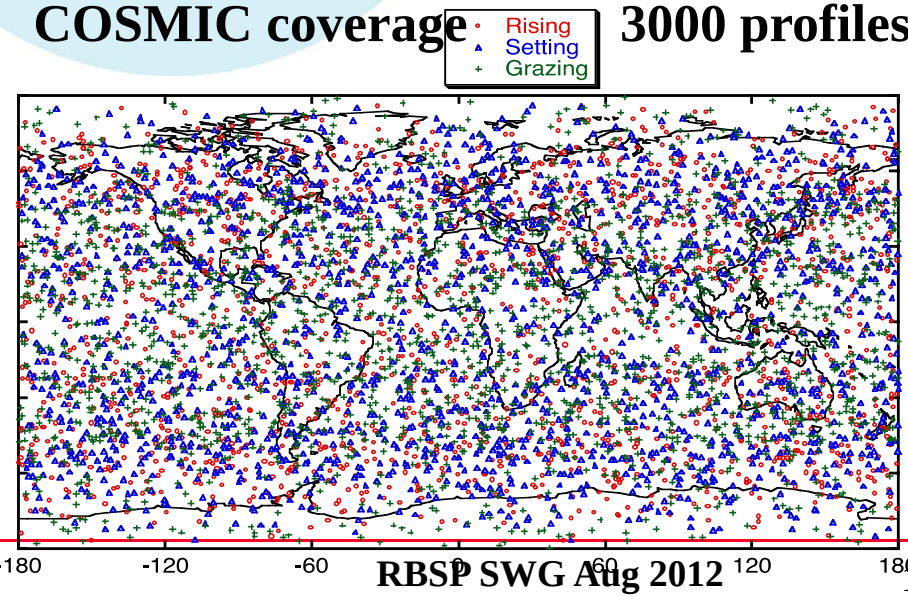
Six-satellite COSMIC constellation
Launch April 2006



Electron Density Profile

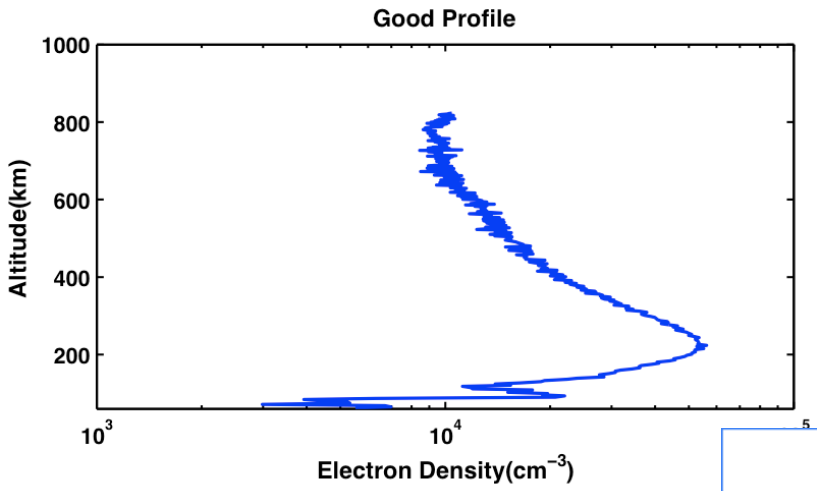


COSMIC coverage **3000 profiles/day**



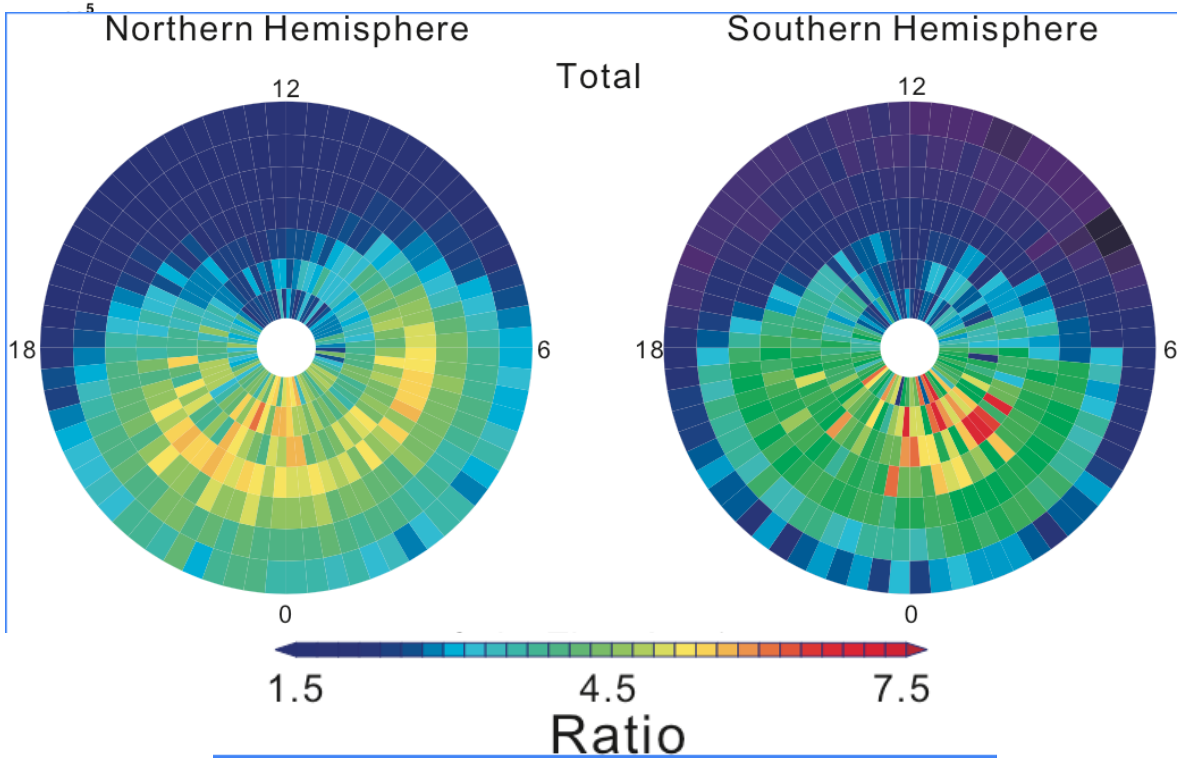
NSF NASA USAF NOAA NSPO ONR

MI Coupling: Ionospheric Conductivity



Electron density profile from COSMIC

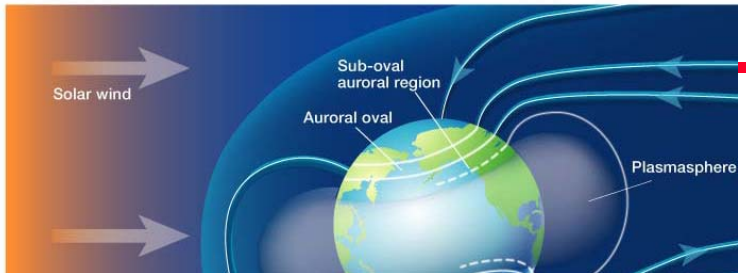
Sheng et al.: "Our result shows the ratio between the E(100-150km) and F(150-600km) region integrated Pedersen conductivities is about 1:5, which is larger than the ratio(1:10) generally expected in the auroral region."



Sheng, Deng (UT Arlington), Huang, Yue "Height-Integrated Pedersen Conductivity of Ionosphere from COSMIC Observations" CEDAR Workshop 2012

Summary

- **Existing TEC observational assets provides RBSP investigators with tools that help answer the RBSP science questions**
  - **Geospace boundaries and plasma convection/electric fields**
- **The thermosphere-ionosphere community has developed observations and models that may help understand the role of solar wind on the radiation belts**
- **Space-based TEC measurements are another resource to provide critical observations for M-I coupling studies**
- **Please help us with the white paper "Radiation Belt Storm Probes Coordination with the CEDAR Community"**
  - **CEDAR supports RBSP: Global Context for In Situ Observations**
  - **RBSP supports CEDAR: Energetics and Electrodynamic Coupling**



Earth-Sun System Exploration 5

January 13-19, 2013

Kona, Hawai'i

"Earth Sun System Disturbances: Weak, Moderate, and Extreme"

Convenors: Patrick T. Newell and Bruce Tsurutani

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http://sd-www.jhuapl.edu/Aurora/ESSE/index.html